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A TECHNICAL ASSESSMENT OF AERONAUTICAL ENGINEERING IN ISRAEL.(U)
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A TECHNICAL ASSESSMENT OF AERONAUTICAL ENGINEERING IN ISRAEL

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A variety of Israeli academic and industrial institutions are discussed with an eye toward assessing research and development activities in aeronautical engineering disciplines. Each institution is described in brief and some of its current research projects are listed. Research in aerodynamics, guidance and control, propulsion and combustion is discussed and industrial product lines are described where appropriate. Some conclusions are drawn in an effort to assess the country's overall capabilities in aeronautical engineer-

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A TECHNICAL ASSESSMENT OF AERONAUTICAL ENGINEERING IN ISRAEL

General

A variety of Israeli academic and industrial institutions were visited with an eye toward assessing R&D activities in aeronautical engineering disciplines. The visits were prearranged through the Israeli government. All information was collected overtly and Israeli technical personnel were, without exception, most willing to discuss their work. The scientists, engineers and technicians displayed obvious pride and confidence in their plans and accomplishments, and all were aware of their contributions to Israel's survival among hostile neighbors.

In general, Israeli industry and academia are most anxious to build a technical relationship with the U.S. Navy. Every institution visited pointed with pride to past and present programs with both the U.S. Army and U.S. Air Force, and each expressed an interest in collaborative efforts with Navy organizations

Arrangements were made with the following ogranizations:

a. Rafael, the Armament Development Authority of Israel, Haifa.
b. Hebrew University, Jerusalem.
c. Weizmann Institute, Rehovot.
d. Ben-Gurion University of the Negev, Beersheba.
e. Technion, Israel Institute of Technology, Haifa.
f. Israel Aircraft Industries (IAI), Tel Aviv.

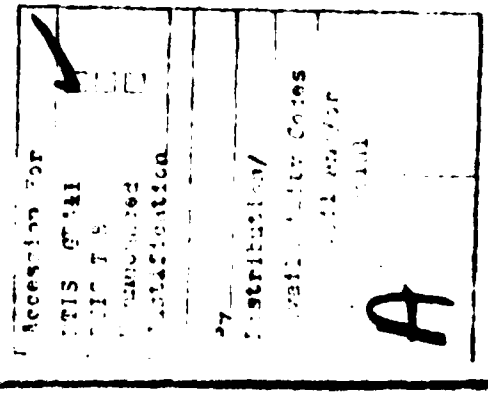
Each will be discussed in turn. The objective is to summarize each organization's general strengths and weaknesses. Specific projects or programs will be referred to when necessary to illustrate an area of expertise.

Rafael

It is most regrettable that due to confusion at the U.S. Embassy in Tel Aviv our clearance to visit Rafael was not obtained in time. Informal discussions with past and present Rafael employees revealed that we would have been welcome there, and the high quality weapons development under way would be of interest to the U.S. Navy.

Hebrew University, Weizmann Institute and Ben-Gurion University

These institutions were strong in basic research into the applied sciences. Work in physics, chemistry, mathematics and materials may have ultimate aerospace applications, but the researchers involved did not, in most cases, view those applications as their chief objective. None of these institutions had a department of aeronautical or aerospace engineering.



The Technion

The Technion is the country's oldest institution of higher learning, having been founded in 1924. It offers degrees in most science and engineering disciplines as well as architecture, town planning and medicine. Although Hebrew is the official language of instruction, English textbooks are used. All technical publications are in English. Some 1,200 graduates a year leave the Technion which, since 1924, has produced over 20,000 engineers, scientists, architects and physicians. More than 70% of Israel's engineers and scientists are Technion trained and the 1980-81 enrollment showed 6,000 undergraduate and 3,000 graduate students spread over 20 departments. The faculty numbers about 1,500 at three campuses in the Haifa area. The main campus, Technion City, occupies 300 acres.

To encourage research here, the Technion Research and Development Foundation Ltd. was founded in 1952. It is a limited liability company which is completely owned by the Technion. The foundation strives to strengthen applied technological research at the Technion by fostering close working relationships between Institute scientists and industry, including the defense establishment. These relationships are promoted in four ways:

a. The Foundation manages R&D projects, carried out by Technion researchers, under contracts awarded by government and private clients.
b. The Foundation carries out research at its own laboratories, under contract to government and private clients. There are six such laboratories; one, for example, is the Israel Institute of Metals.
c. The Foundation is the legal representative of the Technion academic staff in their contacts with industry.
d. The Foundation acts in a liaison role between Technion researchers and potential clients.

The Department of Aeronautical Engineering has a staff of 35 professors who instruct about 320 four-year undergraduate students in five fields of study: structures, aerodynamics, propulsion, turbojets and flight controls. In addition the Department has five research laboratories under its cognizance: Aerodynamic Research Center, Propulsion Laboratory, Combustion Laboratory, Control Laboratory and Structures Laboratory.

The Aerodynamic Research Center has six wind tunnels, covering the low subsonic to hypersonic speed regime, which are controlled from a central room where the operator can regulate air storage tanks, model attitudes, tunnel sensors, tunnel geometry and Mach number, and data collection and analysis equipment. Tunnel monitoring and data collection is accomplished via closed circuit television, schlieren photography, videotape, CRT data plots, a 24-channel Neff analog signal processor and a PDP-11 computer. The Research Center makes high-quality wind-tunnel models, for itself and its clients, using computer-controlled milling equipment and electrical discharge machinery. Because it could not afford to buy wind tunnel balances from Europe or the US, the Center has also launched its own balance laboratory. They developed a unique capability to produce extremely small, six-component balances which they now market at about half the cost of those produced by US competitors. These mini-balances use Constantan (350 Ohm) strain

gages and are calibrated for linear and nonlinear errors. Each balance undergoes extensive testing at the balance laboratory which pioneered the technique of testing the balances on a lathe, thus subjecting them to thousands of force/moment cycles before delivery.

The main areas of aerodynamic research include:

a. Collecting wind tunnel data on a variety of slender axisymmetric bodies at high angles of attack. This work began with Israel's development of the Kfir fighter aircraft, a derivative of the Mirage III. Technion tunnel tests revealed asymmetric body forces from the aircraft's nose at high angles of attack. As a result, a "moustache" was added to the Kfir to control vortex generation, thus regulating body forces. Other Kfir improvements resulting from Technion data were a fixed canard to generate nonlinear lift and a leading-edge sawtooth for the aircraft's delta wing.

b. Low-speed flow visualization work using helium bubbles in a low-speed wind tunnel. The objective is to understand the vortex-breakdown phenomenon over lifing wings. Future plans include using a laser Doppler velocimeter to map vortex trajectories and structure.

c. Development of a vortex-lattice-method computer program, which is three-dimensional and can handle most wing planforms with flaps and ailerons, and slender bodies of revolution, with compressibility corrections up to Mach 0.7. It can accurately predict vortex-induced nonlinear lift and is being extended, in conjunction with wind-tunnel experimentation, to include the effects of vortex breakdown. Further refinements of the program to handle "thick" wings, asymmetric aileron deflection and post-stall aerodynamics are in progress. The department is using the program to study several very practical problems which include wrap-around missile fins (e.g., folding-fin missiles), canard and cruciform-fin missile configurations, wing vortex-rudder interference at high angles of attack (e.g., landing approach), stall/spin phenomena, variable-geometry and "flapping" wings.

The Control Laboratory uses an extensive system of computers, with assorted displays, to develop control, navigation and display concepts and systems. Current projects include:

a. An integrated pilot's display for instrument approaches to landing. Three-dimensional graphics provide the pilot with a tunnel-like display. He flies the aircraft to stay centered in the tunnel. Attitude, altitude, heading and airspeed information also are displayed.

b. A low-cost inertial measurement concept which would provide highly accurate rate and acceleration information without the use of expensive gyros. The idea involves rotating a triad of accelerometers so that they sense not only linear accelerations, but also Coriolis forces resulting from angular accelerations of the vehicle.

c. Precise weapon pointing and vehicle steering during severe aircraft buffeting (e.g., during helicopter landings aboard ship).

d. Development of a Remotely Piloted Vehicle (RPV) simulator for training RPV operators.

The Technion Propulsion Laboratory has four hot test cells which are individually controlled from a safe control room. The aim is basic research rather than hardware development. Experiments in progress include

a T-shaped combuster built to measure instabilities in solid propellant combustion, and a nozzle lined with a synthetic insulation material being tested for its durability under high exhaust temperatures. In the laboratory's safe working spaces a one-dimensional laser Doppler velocimeter, with associated PDP-11 computer, is being used to measure axial flow velocities in reacting and nonreacting flows. In addition, high-speed photography is employed to study the burning surfaces of solid propellants. The latter study has application to solid-fuel ramjets which the Technion is studying.

The Combustion Lab is in its eighth year of turbulent flame investigation. Pulverized coal, atomized oil, and mixtures of both, are under study for their efficiency in commercial energy production. The lab also has built a valveless pulse jet that is currently kerosene fueled and will ultimately operate on natural gas. Its rectangular cross-section is designed for easy measurement of two-dimensional unsteady flow parameters, and the entire tube can be photographed via a high-speed camera which is part of the test apparatus.

In response to requirements of the Israeli Air Force the Technion has been studying the problem of optimal missile avoidance by maneuvering aircraft, considering all aspects of the problem: missle trajectories and dynamics, aircraft evasion maneuvers, missile processing capabilities, aircraft signatures, missile seekers and electronic warfare. The Israelis are trying to answer the question: What is the minimum information required by a missile to develop an effective guidance law, and what are the sensitivies of the guidance parameters?

Israel Aircraft Industries (IAI)

IAI is a state-owned group of aerospace industries which markets over 200 products and 600 services. IAI receives no government subsidies and, because there is no law which requires Israel to "buy Israeli", IAI must remain competitive with foreign producers. Since its founding in 1953 the company has grown to 21,000 employees, 3,700 of whom are graduate engineers; 2,500 of those engineers are involved in R&D. IAI exports exceeded $400 million last year.

The IAI Engineering Division is responsible for the R&D, design and testing of aircraft, missiles and weapon systems. Its most notable achievements are:

a. The Kfir ("Lion Cub") fighter, initially a Mirage III derivative, and the Kfir C-2 advanced fighter, which included improvements like a fixed coupled canard and saw-tooth-leading-edge delta wing.

b. The Westwind business jet, initially a derivative of the Jet Commander. The newest version of this aircraft will employ a supercritical, transonic wing and some composite control surfaces.

c. The Arava STOL transport aircraft which now incorporates winglets to dissipate wingtip vortices. The Arava is exported to both North and South America.

d. The Scout mini-RPV battlefield surveillance system.

e. The Gabriel family of surface-to-surface missiles. There are now three versions (two semiactive and one active) of this short-range missile which sank some 18 Egyptian vessels during the Yom Kippur war. It is exported to ten countries, mostly in South America. The Lavile ("Lion") follow-on fighter is now in planning. It will employ a close-coupled canard, fly-by-wire technology and extensive use of composites. Cooperation with US companies is being sought.

The IAI Electronics Division is composed of several independent profit centers which run the gamut of aerospace electronics:

a. Elta Electronics, which markets ground-based and airborne radars, such as the ELT2001B, which uses Doppler to provide good look-down capability.
b. MBT Weapon Systems, which produces the Gabriel missile system, as well as stability and control systems for aircraft.
c. TAMAM Precision Instruments, which designs, develops and manufactures advanced avionics and inertial systems.
d. MLM Systems Engineering and Integration.

The Combined Technologies Division consists of six independent "sub-companies":

a. Ramta Structures and Systems, which produces armored land vehicles, a "mine plow" vehicle, and patrol boats up to 71 feet in length for the Israeli Navy.
b. SHL Servo Hydraulics, which markets aircraft landing gear for military and civilian users.
c. MATA Helicopters, whose activities include helicopter maintenance and overhaul, and licensed production of helicopter rotor blades and transmissions.
d. PML Precision Mechanisms, which produces electromechanical devices, such as aircraft throttles.
e. Golan Industries, producing airliner seats, ejection seats and 20-mm machine gun magazines.
f. Orlite Engineering.

Finally, the Bedek Aviation Division of IAI provides servicing for 30 aircraft types and 30 different engines, completing 300 aircraft and 1,000 engines per year.

Conclusions

a. Israeli aeronautical engineering, both academic and industrial, was observed to have the following characteristics:

1. It is thorough and professional, founded on a healthy combination of theory and experimentation.
2. It is "results-oriented". Almost all research being conducted is aimed at a specific problem or application.
3. It is largely defense-oriented. A close working relationship between military, industrial and academic scientists and engineers is obvious. The common thread is usually some operational requirement of the Israeli armed forces.

4. It is efficient. The average weapon system design-test-production cycle is very short. Major systems are typically fielded in three years.

5. It is founded on US specifications, parts and blue print/drawing formats. English is the language used.

b. The Israelis are anxious to develop a closer working relationship with the U.S. Navy and are most willing to exchange technical information where feasible. They are obviously interested in competing for US research funds and production contracts. The "Memorandum of Agreement Between the Government of Israel and the Government of the U.S.A. concerning the Principles Governing Mutual Cooperation in R and D", signed on 19 March 1979 as part of the Camp David Peace Accords, is viewed as an avenue of cooperation that our Navy has failed to use. They would like to see that situation remedied.

c. There is something to be learned from the Israeli approach to aeronautical problems and requirements. They are experts at quick, clever, cost-effective solutions that are operationally acceptable and effective.